

THE INHIBITIVE EFFECT OF DIRECT SUNLIGHT ON THE GROWTH OF THE DATE PALM¹

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INTRODUCTION

A study of the habits of the growth of the date palm reveals an adaptation to the conditions of desert climates to which attention has only recently been directed (5, p. 3, 4).²

The lower minimum temperature point for growth has been treated (6), leaving still much work to be done on the optimum and maximum cardinal points for growth. The protective temperature regulation of the growth center and its influence on other temperature reactions, making growth possible the whole year, has been shown (7). The reaction of the date palm and a number of other palm genera to light conditions are considered in the present paper.

The date palm, along with many other palms, has a diurnal period of leaf elongation, in darkness or in the absence of direct sunlight, alternating with a complete cessation of growth in bright sunlight. This diurnal alternation of growth and rest, occurring inversely to the exposure to direct sunlight, is discussed in the following pages.

The literature on the growth habits of the date palm is very meager and the most of it is lacking in definiteness. Branner (1, p. 481) states:

In conclusion I find: (1) That all fronds and spadices originate at the center of the phylophore; (2) that the fibrovascular bundle division continues to grow until its frond reaches maturity; (3) that the growth of a palm trunk continues as long as the bundle divisions of the part are in active connection with living fronds, and no longer; and (4) that the growth of palms is therefore an internal growth, and the term "endogen" is not a misnomer as far as palms are concerned.

The inference that the entire growth of the leaf is made within the "phylophore" (correctly phyllophore) may be drawn from this, but is not positively stated.

A study of date-palm growth involves the questions: (1) In what regions of the plant is the growth made? (2) What relation does growth bear to temperature? and (3) What relation does growth bear to light and darkness?

The experimental approach to these questions calls for methods adapted to the particular structure of the date palm which is distinct from exogenous plants generally and also from many other genera of palms.

TERMINAL LEAF GROUPS

The leaves of the date palm when full grown are distributed around the axis very accurately according to the system of phyllotaxy of the genus; but in emergence from the bud they appear to follow growth impulses or waves in that from three to five leaves emerge together in close contact and with the perfectly formed

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² Reference is made by number (italic) to "Literature cited," p. 468.

pinnae closely appressed, maintaining a growth rate as one individual. The form suggests an acutely sharpened stake for which the writer proposes the name *palus*, from the Latin *pālus*, a stake.

This *palus* or synchronous group of leaves may be extruded to a length of 2 or 3 feet before the new growth from within separates them and they assume an individual rate of elongation.

EXPERIMENTAL DATA

METHODS OF THE EXPERIMENT

In order to determine the various questions of growth in relation to light and temperature, seven seedling trees at the United States Date Garden at Indio, Calif., were selected for observation.

As the *palus* of new leaves emerged from the buds of two of these selected individual leaves were marked into 1 cm. and 10 cm. divisions, in order to learn whether any further elongation was made. The length of unexpanded pinnae was also recorded to learn whether they had attained their full length. In no case was any further elongation of light-exposed portions of either rachis or pinnae observed. A varying portion of the leaf was pushed up daily from the heart of the bud, the movement of which will be discussed later. The depth at which actual elongation of the tissue was taking place could only be surmised from external observations.

Next a discarded male tree about 5 years old was dissected in order to trace the elongation to its source. A sector of one-third of the circumference was cut out to 10 inches below the top of the bud, and two-thirds of the radius toward the center. Without invading the very center of the bud, portions of the bases of several of the younger leaves were reached where the tissue was ivory white, the fibrovascular bundles yet unhardened, and the whole substance easily broken with a square brittle fracture. While these dissections were being made, the admirable binding quality of the fibrous older sheaths was at once apparent. The whole central part of the bud was in a state of tension from the turgescence of the growing parts within. A distinct popping sound could be heard as the tensely strained layer of "leaf" or sheath fiber was severed with a quick cut of the knife and the pressure within relieved. If the leaves in the bases of which lignification had not taken place were not supported at once, they were broken by the slightest swaying by the wind or overbalanced by their own weight. Ten-centimeter portions were marked in centimeters on the succulent exposed portions of five such leaves, and these again marked in millimeters with a needle point.

Here, finally, proof of elongation was secured. The millimeter spaces in the lower portion of the marked areas were found to be farther apart in the daily observations, though the elongation was slight and continued only three days. The slight pushing up of the leaf from below showed that only the upper portion of the elongating area had been exposed. It seems probable that exposure to the air checked the elongation after three days, and that the severe cutting brought the whole growth to nearly the zero point. Subsequent experiments, where holes were bored to the center of the trunk, determined that this pushing up of tissues was quite active 18 inches below the bud crown, and at 2 feet below there was still a discernible action. This mode of growth is referred to as "basipetal" by Jost in the following paragraph: (4)

Frequently we meet with another type of leaf expansion where the apex at once passes into a state of rest. This is the case in many lianes where specially formed apices, fulfilling particular functions, are produced long before the rest of the lamina is completed. The elongation is basipetal also in the long leaves of monocotyledons, owing to the development of an intercalary growing zone at their bases.

Attention has been called (?) to the fact that all of this basipetal growth was so deeply seated in the bud as to be in complete darkness; quite the reverse of the mode of terminal growth of endogenous shoots like the bamboo or in the twigs of exogenous shoots like the apple or the pine, where cell division must go on within translucent tissue, or in very small twigs in nearly full sunlight.

PERIODICITY OF LEAF ELONGATION

Several trees of different ages were selected for study of their leaf growth, five of the newest central leaves being designated by letters, and the trees by their place numbers in the blocks.

The method of recording the advance in growth was by driving stakes, or for taller trees by erecting little towers. Upon these were placed carefully leveled crosspieces, over which a steel square enabled the record marks to be made on the ribs of the leaves with a thin-bladed knife. A day's growth of as little as 1 mm. could be accurately recorded. At first observations were made morning and evening, but the fact was soon disclosed that with occasional exceptions the expansion or pushing up from below took place almost wholly at night.

As it was not feasible at first to keep these records in close coordination with sunrise and sunset, the observations being made about 8 a. m. and 4 p. m., only the general facts of the relation of growth to light and darkness were brought out. Two facts, however, soon gained prominence, in addition to the main one (that the chief growth is made in darkness). The first was that intermittently some growth was made during daylight hours. Whether this was a holding over or prolongation of the night growth, or was due to conditions occurring during the day, could be shown only by securing continuous or auxanometer records. The second fact noted was that certain leaves, and on some days several of them, were actually shorter at night than when the morning reading was made. This interesting phenomenon, which has been observed in the growth history of a variety of plants and is attributed to decreased turgescence of the cells, will be made the subject of further study.

AUXANOMETER DATA

In April, 1918, an auxanometer was installed by making use of an anemometer clock having a horizontal recording cylinder revolving once in six hours. The spirally threaded spindle for carrying the record cylinder laterally to receive the wind velocity record was discarded, leaving the cylinder its rotary motion in a fixed position on its axis, and a pen-carriage was constructed to move from left to right at the pull of the wire actuated by the leaf growth. This clock in its case, was placed on a rigid stand by the side of the tree to be observed.

Since the midrib of the date leaf was quite rigid and pushed upward by a positive expansion below in the heart of the bud, an

upward pull on the fine piano wire fastened to the rib a few inches from its emergence from the bud gave a direct index of the growth being made. A piece of coiled wire tubing fastened rigidly to the palm trunk below the record leaf and to the side of the clock case served as a conduit for the piano wire between its attachments to the leaf and to the pen-carriage. The pen-carriage traveled on two parallel horizontal guide rods, and the beginning of a record was placed at the left hand or distal end of the cylinder. The pull of the wire to the right in response to the growth was counterpoised by a small rubber band on the left, giving a positive and steady motion to the pen. At the same time the position of the band was adjusted to regulate the pen pressure on the record cylinder.

Although this mechanism develops some friction on the wire, and is lacking in the extreme delicacy usually essential to an auxanometer, the strong up-push of the growing date leaf and the rigidity of the rib probably compensated for these features; and the general stability of this device was a positive advantage in out-of-door conditions, with almost constant high winds to be withstood. It is obvious that with this arrangement the pen traces a smooth line around the cylinder and parallel with the base when no growth is made, while growth is recorded by a slowly advancing spiral. As the circumference of the

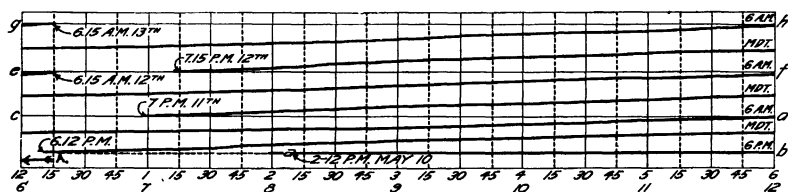


FIG. 1.—Auxanometer record of growth of date-palm leaf at the Government Date Garden, Indio, Calif., May, 1918

cylinder, making one revolution in six hours, is 12 inches, the cylinder must rotate past the pen one-sixth of 12 inches or 2 inches in one hour. Hence each five-minute period would be represented by one-twelfth of 2 inches or one-sixth of an inch on the circumference of the cylinder; while the longitudinal progress of the pen on the cylinder, actuated by the pull on the piano wire, would record the actual growth made.

This secures a fairly accurate recording of the beginning and ending of the growth periods, as well as a comparison of the growth rate during the different periods of the night.

When no day growth is made the pen does not advance and the pen-trace runs around the cylinder as a single line parallel to the cylinder heads at the point where growth ceased.

Between sunrise, when growth ceases, and sunset, when growth is resumed, the cylinder would make nearly two complete revolutions with the pen tracing the same mark.

Table I shows the daily growth, in millimeters, before and after midnight, with the time of beginning and ending from April 24 to May 20, inclusive. Figure 1 reproduces a tracing from one of the record sheets, most typical of three days' growth. (One should imagine this wrapped around the cylinder, with *c* and *d* contiguous and revolving in the direction of the arrow *A*.)

The horizontal lines *c-d*, *e-f*, and *g-h* show two revolutions of the drum during sunlight without registering growth. The heavy lines

ascending from left to right show night growth beginning at 6.12 p. m., 7 p. m., and 7.15 p. m. on April 10, 11, and 12, respectively, and ending 6 a. m., 6.10 a. m., and 6.15 a. m.

TABLE I.—*Daily growth of date palm before and after midnight, with time of beginning and ending from April 25 to May 20*

Days	Hour growth was re- sumed	Min- utes before sunset	Hour growth ceased	Min- utes after sunrise	Growth before mid- night	Growth after mid- night	Total growth	Excess of growth before mid- night	Excess of growth after mid- night
	<i>p. m.</i>		<i>a. m.</i>		<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>
Apr. 25 to 26	5.50		6.12		8.0	9.0	17.0		1.0
Apr. 26 to 27	5.57		6.30		10.0	8.5	18.5	1.5	
Apr. 27 to 28	5.40		7.30	80	9.5	10.5	20.0		1.0
Apr. 28 to 29	6.50	15	7.05	52	8.0	11.0	19.0		3.0
Apr. 29 to 30	7.12		6.42	29	7.5	9.5	17.0		2.0
Apr. 30 to May 1	5.20	108	6.33	15	8.0	10.5	18.5		1.5
May 1 to 2	7.05		8.10	120	8.0	10.0	18.0		2.0
May 2 to 3	6.15		9.50	189	9.0	13.0	22.0		4.0
May 3 to 4	5.55	85	8.35	223	10.5	12.5	23.0		2.0
May 4 to 5	6.12	69	6.55	50	12.0	12.0	24.0	0.0	0.0
May 5 to 6	7.05		9.00	170	8.5	11.0	19.5		2.5
May 6 to 7	6.25		7.30	80	10.0	10.5	20.5		0.5
May 7 to 8	4.32	161	8.35	145	12.5	10.0	22.5	2.5	
May 8 to 9	4.52	148	6.45	33	11.0	8.5	19.5	2.5	
May 9 to 10	5.00	148	10.00	220	11.5	9.5	21.0	2.0	
May 10 to 11	6.10	70	5.47	21	8.0	6.5	14.5	1.5	
May 11 to 12	6.55	32	6.15		9.0	9.5	18.5		0.5
May 12 to 13	7.16	10	6.15		9.5	10.5	20.0		1.0
May 13 to 14	6.50	30	7.50	110	8.5	12.5	21.0		4.0
May 14 to 15	7.00	20	6.12	8	10.0	13.0	23.0		3.0
May 15 to 16	5.22	125	9.00	180	12.0	10.0	22.0	2.0	
May 16 to 17	7.10	20	6.45	36	10.0	10.0	20.0	0.0	0.0
May 17 to 18	6.43	51	8.03	60	10.0	10.0	20.0	0.0	0.0
May 18 to 19	6.23	75	8.05	102	9.0	11.0	20.0		1.0
May 19 to 20	6.15	75	7.52	110	12.0	9.5	21.5	2.5	
May 20 to 21	6.12	78	8.28	148	10.0	12.0	22.0		2.0

Figure 2 shows the daily growth for nine successive days (May 10 to 19) plotted to a uniform scale; a single line for each night's growth ascending from left to right between the horizontal lines of no growth during sunlight. The vertical lines show the hours of growing time before and after midnight, with the lines of heavy dashes indicating approximately the time of sunset and sunrise.

In a general way both Figures 1 and 2 and Table I show that the growth activity began at a variable time before sunset, progressed rather uniformly through the night and to a period of from a few minutes to two or three hours after sunrise. The excess of growth in the periods before and after midnight appears to depend on the prolongation of the growth period by the light being obscured by clouds and dust, so that normal growth may be regarded as nearly uniform throughout the hours of darkness. It should be noted also that the growth rate in obscured sunlight (for example, the evening of May 15 and the morning of the 16th) is invariably slower than that during full darkness.

Correlated observations on the weather conditions showed that when the air was clearest the beginning of growth was retarded the nearest to sunset, and growth ceased soonest after sunrise. With clouds over the mountain top to the west, obscuring the sunset, or with the air heavy with fine sand driven by winds from the same direction growth began at an earlier hour. After all-night winds which filled the air with dust, or with vapor present in the morning

air, growth was proportionally prolonged after sunrise. In other words, growth in the form of leaf elongation is for the date palm somewhat inverse to the light intensity. It is most active in darkness, nearly or completely checked in bright sunlight, and partial in obstructed light.

GROWTH REACTION TO ARTIFICIAL LIGHT AND DARKNESS

In order to be able to determine more definitely the relation of date leaf growth to light and darkness it was deemed necessary to provide for the exclusion of light at will. In order that otherwise normal growth conditions might not be disturbed, a folding dark cell was constructed which could be placed around a medium-sized palm in the field in a few minutes time. Four panels of light pine framework, each 5 feet wide by 12 feet high, were covered with black enameled cloth (the black surface within) to prevent excessive heating in the sunshine. Three of these panels were hinged together and when erected around the tree the fourth side was slipped into rabbeted

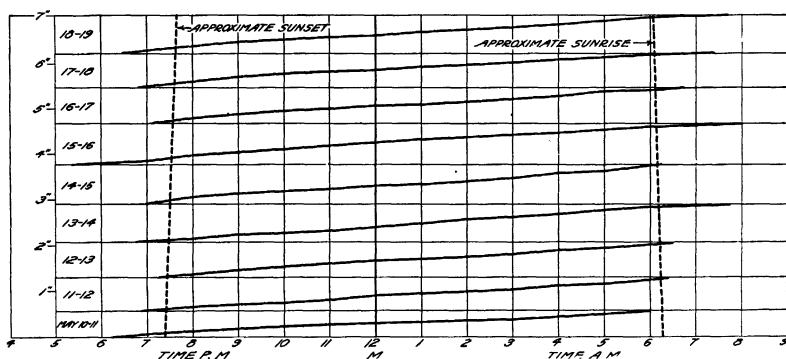


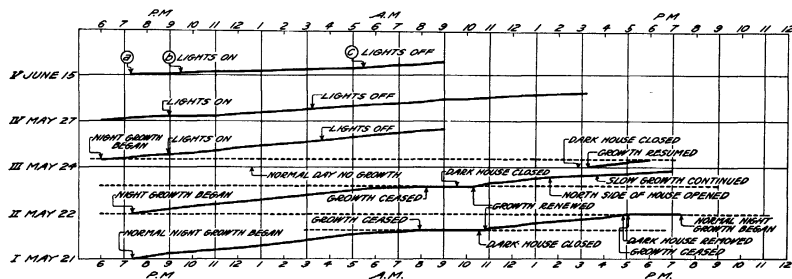
FIG. 2.—Daily and hourly growth of the leaf of Mactoum seedling date palm, plotted from auxanometer sheets, May 10 to 19, 1918

jams provided to secure light-tight joints and held in place by hinged hasps. With the aid of high stepladders, the top, built like a box lid, was placed in position and also secured with hasps. Thus in a few minutes the date palm, with its spreading leaves drawn by cords into a more erect position (the only disturbance to its natural condition of growth) was inclosed in a completely dark cell or chamber 5 by 5 by 12 feet in size (300 cubic feet capacity). At first the auxanometer and stand were retained inside the dark cell, but it was found more convenient for observation to carry the recording wire through the house wall to the stand with instrument outside.

The first test was made on May 22. After a normal gain during the night of the 21st and 22d, growth had come to a complete standstill at 8 a. m., as shown by the auxanometer tracing, Graph I, Figure 3.

At 10.37 a. m., after 2 hours 37 minutes record of no growth, the dark cell was closed and remained in position till 4.55 p. m. As the actual auxanometer records are somewhat difficult to interpret, they have been transferred to graphs similar to the day and night records in Figure 2, but the time in hours is represented by one-half inch spaces, while the actual leaf growth is represented in the inch and

From this the horizontal line till 7.25 p. m. indicates that the normal daylight dormant condition as to elongation was resumed in a very few minutes after the plant was exposed to the normal sunlight and continued until the usual night elongation commenced, which was 13 minutes before sunset. In Graph II this night growth is transcribed from 7.25 p. m. May 22 till 8.20 a. m. May 23, from which point a horizontal line of no growth continues till 10.15 a. m., 35 minutes after the dark cell was closed at 9.40 a. m. Apparently when the sunlight was shut out the growth did not start quite so promptly as on the previous day. Here the lack in sensitiveness in the recording mechanism is to be regretted, as a precise reaction time can be only



approximated. On this day the dark cell was opened at 1.37 p. m. by removing the panel on the north side. With the top and three sides remaining in position the tree was still deprived of direct sunlight, receiving only the reflected north light, much of which was absorbed by the black interior walls, giving about the effect of a dull cloudy day. Instead of the growth being wholly checked, as when the dark cell was entirely removed and the tree exposed to full sunlight on the previous day, growth continued as shown by the graph at a less rapid rate than in complete darkness. Therefore exposure to full direct sunlight must be assumed as one of the conditions for growth cessation.

It has been suggested that in securing the resumption of growth within the dark cell at midday other factors than the complete darkness may have been involved, as a marked rise in temperature and an increase in the relative humidity. The reply would be that growth action was recorded before there was time for any very marked change in either temperature or humidity. Moreover the continuation of growth with the north side of the dark sell removed was made under conditions where but little gain in temperature could have resulted, and no increase in humidity, leaving the continuance of growth under partial lighting to be ascribed wholly to the absence of direct sunlight.

GROWTH UNDER ARTIFICIAL LIGHTING

In order to test the converse side of this problem it was next proposed to learn whether active growth in the night could be checked by exposing the tree to artificial lighting. Electric wires from a lighting circuit of 110 volts were carried to the dark cell and two 200-watt incandescent bulbs and two 60-watt bulbs installed, giving an illumination of 520 watts. At 2.53 p. m. May 24, as shown by Graph III, in Figure 3, the dark cell was closed around the tree and active growth was recorded in about 25 minutes. After this growth in darkness had progressed till 9 p. m., the lights were switched on and kept burning till 3.40 a. m., though the dark cell was retained in position till 9 a. m. The gain in growth was practically uniform through the entire period of nearly 18 hours. No checking of growth could be traced to the effect of this degree of illumination. A preliminary trial had, in fact, shown that the cell of 300 cubic feet of space was rather feebly lighted owing to the absorption of light by the black walls. Yet the same number of watts brilliantly illuminated the station office room, 22 by 16 by 10 feet high, or more than 10 times the cubical capacity of the dark cell. The dark cell was next lined with heavy white cotton sheeting and the lighting increased to six 200-watt bulbs, or 1,200 watts. The dark cell was closed at 5 p. m. May 27 and active growth was registered at 6 (Graph III). At 9 p. m. the lights were switched on. This was followed by no growth for two hours or until 11 p. m. At this point the growth was resumed and, until the lights were switched off at 3.15 a. m. May 28, continued at practically the same rate of growth as in full darkness until the dark cell was removed at 3.15 p. m. May 28.

This experiment was repeated in June under the supervision of Bruce Drummond. The lighting was increased to 1,800 watts and the dark cell was erected around the palm on June 15 and normal darkness growth began to be registered shortly after 7 p. m., as shown in Graph V, *a* in Figure 3. At 9 p. m. (*b*) lamps to the volume of 1,800 watts were switched on and continued until 5.30 a. m. of the 16th (*c*). The gain made during these eight hours of illumination was only 3 mm., but from the time the lights were switched off till 9 a. m. of the 16th (3.5 hours) a gain in the dark cell of 3 mm. was also made. In other words, the growth during the eight hours of intense illumination was at the rate of 0.375 mm. per hour, while that during the ensuing 3.5 hours of complete darkness was at the rate of 0.857 per hour. The illumination reduced the growth rate to 43.7 per cent of the rate in darkness. Consequently even so vivid an illumination as that given by 1,800-watt incandescent lamps within this small space of 300 cubic feet, while slowing down the growth rate to less than half, fails to give the complete check which is observed in the ordinary intense sunlight of this station. Evidently a difference in the quality of the rays from the incandescent lamps and those from the sun must be more important than their difference in intensity. The facilities of the Indio field station could take the work no further.

LABORATORY WORK AT WASHINGTON D. C.

A laboratory opportunity for testing the action of date palms under light of a different quality was afforded by the presence in one of the department photographic rooms of two powerful "Cooper-Hewitt"

mercury vapor electric lights working on a 220-volt direct current circuit. These have 50-inch lead glass tubes of "Type P," and are rated by the manufacturers as consuming a current of 385 watts each. Two seedling Thoory palms in 8-inch pots, having leaves in active growth, were selected and prepared for growth measurement by placing in the pot small standards carrying a horizontal gauge piece close to the midrib of the leaf to be recorded. Glass-headed steel ribbon pins were inserted for markers in the leaf rib in contact with the gauge.

A very slight degree of growth could thus be detected by the light being visible between the pin and the gauge, and this space was readily measured by the gentle insertion of one or more thicknesses of paper. Their total thickness was measured with a micrometer caliper gauged to 0.001 inch, but easily read to the half space. As in the artificial light tests at Indio, Calif., it was arranged to record first a period of active growth in complete darkness, then a period of exposure to the light, followed by a second period in darkness.

In preparation for the test the plants were placed in position between the mercury vapor tubes and well below them so that the reflectors would give them the full light. The room was completely darkened from 4.30 to 8 p. m., October 2. Then the 3½-hours' growth in darkness was measured, the pins put down to the gauge and the mercury lights switched on. After an exposure from 8 p. m. until 12 midnight the growth indicated was only the thickness of one sheet of paper (0.002 inch) on palm No. 1, and of two sheets (0.005 inch) on palm No. 2, which may have been a continuation of the darkness growth before the check. Left again in darkness till 8.30 a. m. of October 3, the gauge showed that the growth must have been quickly resumed, as 0.0245 inch of growth was recorded for each plant. The exposure was repeated the night of October 3 under the same conditions, but with a slight modification in time, the results confirming the first night's record. Table II shows the growth in thousandths of an inch for both nights.

TABLE II.—*Growth of two date palms during the nights of October 2 and 3*

Date and hours	Growth made by tree No. 1	Growth made by tree No. 2
	<i>Inch.</i>	<i>Inch.</i>
Oct. 2, 4.30 to 8 p. m.	0.0130	* 0.0080
Oct. 2, 8 to 12 m. ....	.0020	• 0.0050
Oct. 2 to 3, 12 m. to 8.30 a. m. ....	.0245	* .0245
Oct. 3, 4 to 8 p. m. ....	.0250	* .0250
Oct. 3, 8 to 11 p. m. ....	.0025	• .0025
Oct. 3 to 4, 11 p. m. to 8.30 a. m. ....	.0340	* .0500

* In darkness.

• Under light.

The interpretation of these records, showing only a minute amount of elongation during the lighted period, seems clearly to be that after the early evening growth in darkness the exposure to the mercury vapor rays checked the growth wholly after a lapse of a few minutes. This reaction period is similar to that found to occur between darkness and sunlight action in the Indio tests.

The rays of the mercury vapor lights appear to have checked the leaf elongation as perfectly as did bright sunlight under Indio conditions, a result not attained with much more intense illumination by incandescent bulbs.

The next step is to compare the spectrum of the incandescent lights and the spectrum of the mercury vapor lights with the solar spectrum. Rays of the solar spectrum, which are lacking in the spectrum of the incandescent lights but present in the spectrum of the mercury vapor lights, must be the important rays in the physiological activity of the date palm, and presumably in that of the other palms which make their leaf elongation chiefly at night.

The subject of the effect of light rays of various colors on the growth of plants has occupied a great deal of attention for more than half a century, and many writers have contributed to its literature. Growing plants in light passed through glass plates of different colors or through colored solutions has shared the field with tests of growth under different portions of the prismatic spectrum. Electric-light culture has also received its full share of attention. The whole subject of the influence of light rays from different regions of the spectrum upon the physiological action of plants is too complex for more than brief consideration.

The writer is not aware, however, of any comparison of growth reaction having been made between light from ordinary incandescent bulbs and light from special illuminants, which either afford a close approximation to pure white light or exclude certain portions of the spectrum, as is done by the Cooper-Hewitt types of lamps.

The Smithsonian Tables 361 and 366 give the following wave lengths, in microns, for the standard colors (2):

Violet.....	0. 44
Blue.....	0. 46-0. 48
Green.....	0. 50-0. 52-0. 54
Yellow.....	0. 56-0. 58
Orange.....	0. 60-0. 62-0. 64
Red.....	0. 66-0. 68-0. 70

The same volume, Table 368, gives the visible spectrum as ranging from 0.644μ to 0.405μ and the ultra-violet from 0.384μ to 0.280μ .

R. D. Mailey, of the engineering department of the Cooper-Hewitt Electric Co., Hoboken, N. J., wrote as follows, in a letter dated October 9, 1918: "The lamps which you are using are made of lead glass, and you will have to keep this in mind, remembering that lead glass does not pass appreciable amounts of light below wave lengths of $3,800 \mu$."

According to the Smithsonian Table 368 (2) the ultra-violet rays begin with wave lengths of 0.384μ , which would leave practically no ultra-violet rays in the radiation from these tubes.

Mr. Mailey did not state the limit of wave length of these tubes in the direction of the red, but fortunately R. A. Steinberge, of the Bureau of Plant Industry, United States Department of Agriculture, had made a spectroscopic analysis of the rays from the identical tubes from which the results under discussion were obtained. These notes he kindly placed at my disposal. Five lines were observed with a hand spectroscope; a bright line in the violet at about 0.405μ , and one in the blue, a faint line in the blue-green, a strong line in the green, and one in the yellow at about 0.578μ . Nothing was visible in the higher wave lengths.

W. W. Coblentz, in charge of light investigations in the United States Bureau of Standards, informally places the three light sources under consideration as follows:

Order of intensity

Ultra violet and violet:

- I. Sun.
- II. Cooper - Hewitt lead - glass mercury lamps.
- III. Incandescent lamps.

Red and infra-red:

- I. Incandescent lamp.
- II. Sun.
- III. Cooper-Hewitt lamps.

Summing up, on one side, the factors under which leaf growth occurs, and, on the other, those under which no growth occurs, the following result is obtained:

Date-palm photo-activity

Growth occurs:

Normal growth—

- a. In total darkness, at night or in a closed chamber.
- b. In chamber with incandescent lights, giving brilliant illumination.

Partial growth—

- c. During cloudy days.
- d. On clear days; with plant exposed to indirect light.
- e. In closed cell with 1,800-watt illumination.

No growth occurs:

- a. Under bright sunlight.
- b. Under Cooper - Hewitt lead-glass tubes.

Analysis of light conditions

Normal growth:

- a. In absence of all light rays.
- b. Under incandescent lamps. Complete spectrum but rays rich in red; no ultra-violet.

Partial growth:

- c. In absence of direct sunlight; proportion of spectrum unknown.

No growth:

- a. Under full solar radiation with intense illumination of atmosphere low in water vapor.
- b. Under Cooper-Hewitt lead-glass tubes; lacking red and orange; containing some yellow, full green, blue, and violet.

Jost (4, p. 127) concludes:

A comparison of observations derived from *all* the researches which have been made brings out the following points: (1) Only light of wave lengths between 770 $\mu\mu$ and 390 $\mu\mu$ is conducive to assimilating activity in green plants; these are approximately the same rays which are visible to us; (2) the assimilating effect of different rays is unequal, but still not in such a way that some are active whilst others lying beyond these are quite inactive.

Jost's estimate of available wave lengths, it will be noted, includes considerable infra-red.

For the position of the apex of assimilation, Jost refers to "Figure 27," adapted from Reinke (9, *pl. 1, fig. 6*); but in Reinke's original figure, while the apex is shown at about the Fraunhofer line B, efficient assimilation is shown down to 600 $\mu\mu$, which includes all of the orange, and considerable activity is shown down to the line D, which is about the upper limit of the rays from the Cooper-Hewitt tubes.

Palladin (8, p. 26), after discussing many intricate features of the problem, sums the matter up as follows: "Carbon-dioxide is thus seen to be decomposed most rapidly in green plants by the light rays between lines B and C."

In the date-palm experiment leaf growth is continued under brilliant illumination from incandescent lamps rich in red rays, while it is inhibited under Cooper-Hewitt tubes which emit no red rays, but are rich in rays of the shorter wave lengths.

That this is simply a rest period for this particular function, while other vital activities of the tree are in full progress is self-evident.

DAYLIGHT ACTIVITY OF THE DATE PALM

The next inquiry should be, What normal activities of the palm in sunlight are inhibited in darkness? According to general principles of plant physiology they would be: First, photosynthesis or the assimilation of carbon-dioxide; second, the greater proportion of the day's transpiration. From the records of leaf elongation in darkness it appears that in the case of palms such action is diametrically opposed to the daylight activities. The one begins where the other ceases. Whether the leaf elongation during the darkness or absence of direct sunlight is the result of cell multiplication with cell elongation, or of cell elongation only, is a question difficult of determination, but probably the whole cell constructive work of the phillophore is performed during this period.

The intense transpiring activity of date palms during heated days has been referred to in another paper by the writer (7) and this is accompanied by photosynthesis on a corresponding scale. There is evidently a close relation between the day's assimilation and the growth of the following night; which is proved by the close correlation between the daily growth curves and temperature curves. But this general relation would not explain the almost immediate growth reaction in response to artificial darkness produced in the middle of a bright day; nor the quick checking of growth when sunlight is restored. If the governing action of the stomates on transpiration is conceded, then by supposing that the stomates close in darkness or partial shade, the checking of transpiration must follow with increased turgescence of the cells in the meristematic region.

In this connection there may be much significance in the recently published studies of Gray and Peirce (3) on the reaction of the guard cells and the opening or closing of the stomates of barley, oats, rye, and wheat on exposure to bright sunlight or in its absence. These authors found that under the conditions at Stanford University, Calif., the stomates began to open on bright days soon after sunrise, reaching the fullest expansion from about 11.30 a. m. to 2.30 p. m., and gradually closed as the sun declined. When only portions of the day were bright, the curve of stomatal opening corresponded to these bright portions. On wholly dark days the stomates remained closed. They also found that if two pots of plants in similar condition, both showing the stomates partially open, were taken for experimentation, the plant in the pot subjected to darkness (with other conditions unchanged) soon closed its stomates. But the plant left in continued light (with other conditions unchanged) soon expanded its stomates completely. Reversal of the exposure of these two pots resulted in a reversal of the reactions of the plants.

Now, the conditions as to light and darkness were practically similar to those under which the Indio, Calif., date palms were observed. Where the date palms began growth the cereal plants of Gray and Peirce closed their stomates; where the date palms

fully ceased elongation at sunrise the grain plants showed steadily increased openings of the stomates; and where the date palms resumed growth under darkness supplied at midday, the grain plants closed their stomates.

In the absence of observations on this point it is reasonably safe to assume that the stomates of the palms react toward light in the same manner as those of the grasses.

While the original habitat of the date palm is only a matter of conjecture, in the cultivated state it is at home in the intense light and heat of the desert. Yet the intensity and quality of light under which it thrives, and especially under which it makes its best development of fruit, have heretofore received little attention. But evidence is not lacking that light conditions are second only in importance to temperature conditions for the growth of this tree. Walter T. Swingle (10, p. 58) anticipated this in 1904 when he wrote the paragraph on "Sunshine necessary for the date palm."

In the writer's study of the date palm in the northern Provinces of Sudan, a region of intense sunlight and dryness of the air, it was found that the native growers appreciated the necessity of the full exposure of the date-palm crown to the sun's rays. They have a system of allowing several offshoots or "daughters" to grow up to full maturity around the "mother" tree, thus giving a much larger number of stems to the acre than could be tolerated in America. Yet if one of these becomes overshadowed by a stronger growth the fact is at once recognized that its vigor and fruit production are seriously impaired.

SUMMARY

Date palm leaves are formed from the top of the phyllophore or growth center deep in the interior of the terminal bud, protected from light and from wide ranges of temperature.

The leaves, in groups of from three to five, called a *palus* are pushed forward by basipetal or intercalary increment, no alteration in their length occurring after they reach the light and assume their green color.

Normal growth, as manifested by the pushing up of the leaves from the growth center, is made chiefly in the time between sunset and sunrise, but also at a reduced rate in daylight, when direct sunlight is cut off by clouds. In full sunlight date palm leaf elongation entirely ceases.

Date-palm leaf growth may be induced in darkness obtained by inclosing the plant in a dark chamber, at any hour of the day. Partial growth may be induced in a similar manner by screening the plant from direct sunlight, but giving it exposure to north or reflected light.

Growth begun in darkness was continued at practically the normal rate when the plant was exposed to a battery of Mazda electric lights giving brilliant illumination.

When date plants after beginning growth in a dark room were exposed to the rays of Cooper-Hewitt lead-glass mercury vapor tubes, the inhibiting of growth was as prompt as in direct sunlight.

A spectroscopic analysis of the rays from Cooper-Hewitt lead-glass tubes shows that this light is confined to rays from the shorter wave lengths of the visible spectrum through violet, blue, green, and yellow to about the line D (0.578μ). The orange and red are completely absent.

It must be concluded, then, that the inhibiting of the date-palm leaf growth in intense sunlight of the desert regions is due chiefly to the action of rays of wave length from about $0.57\ \mu$ in the yellow to about 0.405μ in the violet end of the visible spectrum, but invisible ultra-violet rays probably assist in stopping growth.

Photosynthesis is most active in longer wave lengths from the line D at the end of the yellow to lines B and C in the red; thus growth is inhibited by light that has but little potency in photosynthesis and conversely carbon assimilation is favored by light that has but little ability in inhibiting growth.

Growth in absence of direct sunlight is apparently synchronous with the closing of the stomates, checking of transpiration, and increased turgescence in the meristematic tissue.

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